Full-Scale Vehicle Crash Tests on Nebraska Rural Mailbox Designs

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The Nebraska Department of Roads, in conjunction with the Federal Highway Administration, has developed a new mailbox support system that could be used to accommodate a wide range of mailbox sizes. To be considered a safe appurtenance, the system had to be subjected to full-scale crash tests, as provided in recommended procedures published by the Transportation Research Board, March 1981. The major concern was to find whether the support system would keep the mailbox attached to the post and would not allow detached elements to penetrate the passenger compartment of a vehicle. Four full-scale crash tests were conducted with an 1,800-pound vehicle. Two tests with the post embedded in weak soil were performed at 20 mph and 60 mph, respectively. Two tests with the post embedded in strong soil were conducted at the same speeds. Three of the tests used a support system that held two mailboxes (Size 1-A). One test used a system that supported one mailbox (Size 2). After analyzing the results of the crash tests, it was evident that all of the performance criteria had been met. The major criteria evaluated were change in velocity (maximum 0.010 seconds average deceleration), whether the support system kept the mailbox attached to post, and whether the vehicle remained stable and upright during and after the impact.

Recent federal requirements have mandated that safe mailbox support systems be designed to yield or break away if struck by a vehicle. The Nebraska Department of Roads (NDOR), in cooperation with the Federal Highway Administration (FHWA), has developed a bracket for attaching the mailbox to the support post. The mounting bracket system was designed to adapt to a wide range of mailbox sizes. For the new attaching bracket to be certified as effective, it had to meet the criteria provided by the National Cooperative Highway Research Program (NCHRP) for conducting full-scale crash tests (*1*). If it met those criteria, it could then be considered a safe mailbox support system and become installed on the federal, state, and local highway systems.

It was decided that two mailbox support systems were to be tested. The systems were to be mounted to the Franklin Steel Eze-Erect signposts, which had been crash tested in the past (*2–5*). Thus, it was known that the post itself had already met the NCHRP criteria (*1*). The major concern now was whether the mailbox would remain attached to the post. A second concern was whether the mailbox or detached fragments would penetrate or show potential for penetrating the passenger compartment of a vehicle or present undue hazard to other traffic.

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FULL-SCALE CRASH TEST DETAILS

Test Description

Four full-scale crash tests were conducted on mailbox supports shown in Figures 1 and 2. Three of the tests used two mailboxes (Size 1-A) mounted side by side. The fourth test used

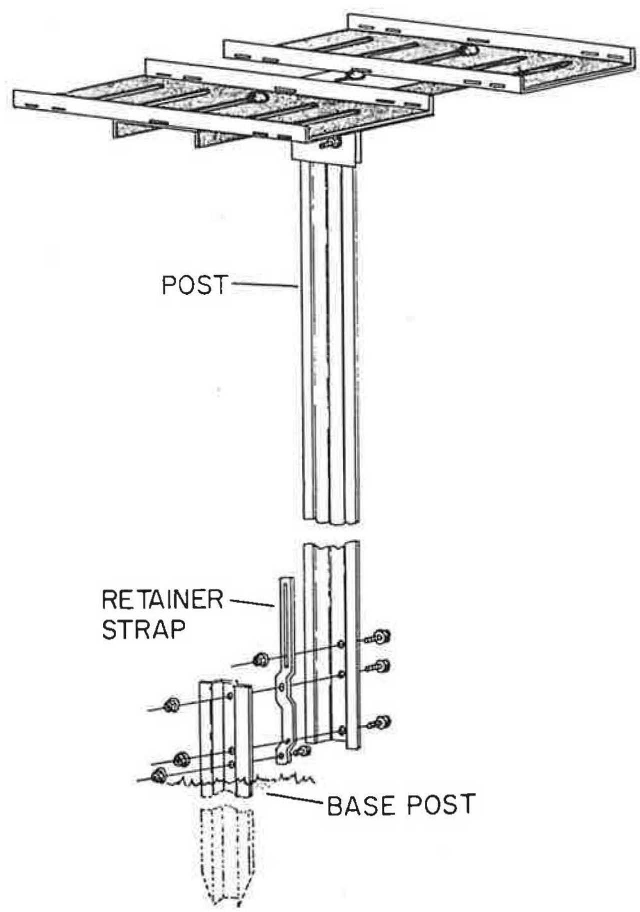


FIGURE 1 Double mailbox support system.

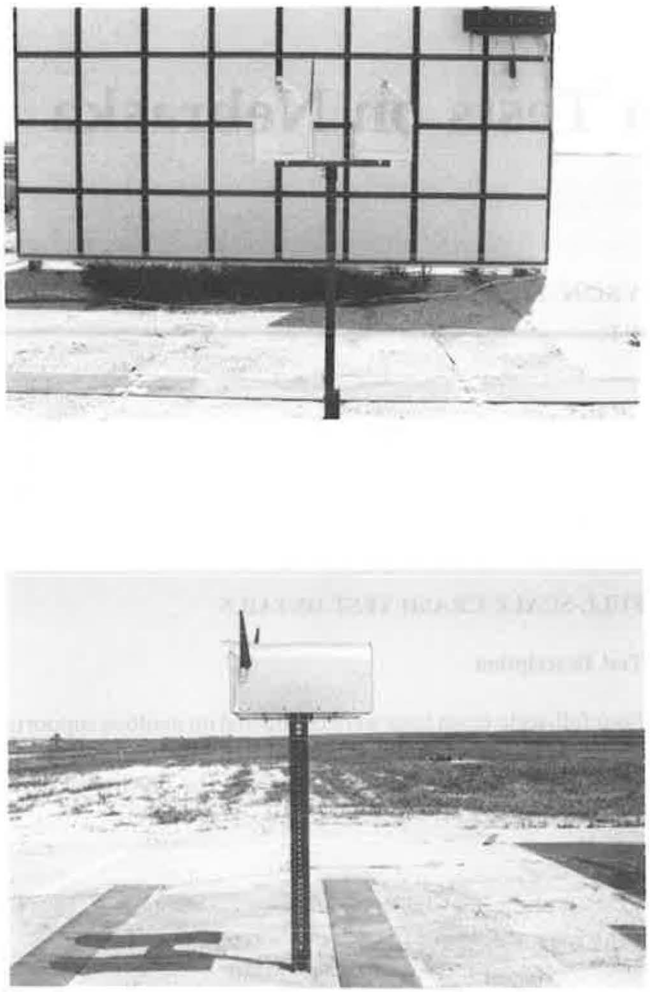


FIGURE 2 Photographs of the complete double mailbox system.

one mailbox (Size 2) mounted to the post. Table 1 contains a summary of the test conditions.

Tests 1 and 2 were conducted in weak soil (S-2) and strong soil (S-1), respectively, at approximately 20 mph. Tests 3 and 4 were conducted in weak soil (S-2) and in strong soil (S-1), respectively, at approximately 60 mph. The 20-mph tests were performed with the impact at the quarter point of the bumper, in accordance with NCHRP 230 (*1*). The 60-mph tests were performed with the impact at the center of the bumper. For 60-mph tests, NCHRP 230 provides that a quarter point of bumper be used for the point of impact. But according to AASHTO 1985 (*6*), the 60-mph, off-center impact recommended by NCHRP 230 may be more stringent than current testing procedures can meet, and thus that acceptance should be based on a center of bumper, high-speed test.

According to the recommended test procedures, a weak soil (S-2) may be appropriate for breakaway/yielding supports. However, due to the variation of soil properties in Nebraska, it was decided that strong soil (S-1) also be used for the crash test. Two pits 10 feet long, 8 feet wide, and 5 feet deep were excavated and filled with strong soil (S-1) and weak soil (S-2), respectively. The soil properties and compaction procedures at the test site met the guidelines given in NCHRP 230 (*1, 7*).

TEST ARTICLE DETAILS

Two mailbox support systems were tested (*7*). The first mailbox support system was used to support two mailboxes (size 1-A) that were 8 inches wide, 21 inches long, and 10½ inches tall. A pair of platform plates was bolted to the bottom of each mailbox. The two plates can be adjusted to fit any standard width mailbox. The two mailboxes, with the platform plates, were mounted directly onto the adapter plate or shelf. Then two L-shaped brackets were used to attach the adapter plate or shelf to the U-shaped post. The double mailbox support system is shown in Figure 1, and the complete system is shown in Figure 2.

The second mailbox support system was used to support one mailbox (Size 2), which was 11½ inches wide, 23½ inches long, and 13½ inches tall. A pair of adjustable platform plates was bolted to the bottom of the mailbox. The larger mailbox, with the platform plates, was mounted directly to the post with a pair of L-shaped brackets. The single mailbox support system is shown in Figure 3, and the complete system is shown in Figure 4.

The post system consisted of four main parts—the top post, the base post, the retainer strap, and the anti-twist plate. With the exception of the anti-twist plate, the post system is shown in Figure 1.

The top post was 42 inches long and had the cross-sectional dimensions and values as given in Table 1 (*7*).

The base post, which was embedded 37 inches into the soil, was also 42 inches long and had the same dimensions as the top post. Both the top and base post are fabricated from rerolled rail steel.

The 17-inch long retainer strap was used to connect the two post sections together. The installation instructions for the Franklin Steel Eze-Erect sign posts are given in a report on full-scale crash tests on Nebraska rural mailbox designs produced by the University of Nebraska-Lincoln in August 1987 (*7*).

The anti-twist plate was made from a ⅛-inch sheet of galvanized sheet metal. It was trapezoid shaped, with the following dimensions: top horizontal length 12 inches, bottom horizontal length 6 inches, and height 6 inches. It was bolted to the base post so that it would be positioned below ground level.

TEST VEHICLE

A 1979 Volkswagen Rabbit, weighing approximately 1,840 pounds, was used as the crash test vehicle.

DATA ACQUISITION SYSTEMS

Two piezoresistive accelerometers (Model 7264) with a range of 200 *g*, were used to measure the accelerations in the longitudinal direction of the vehicle. The accelerometers were attached to metal blocks which were mounted to the front floorboards on both sides. The signals were first sent to the Metraplex FM multiplexed data acquisition system (Series 300), then to the Honeywell 101 analog tape recorder for permanent storage.

Two cameras using high-speed film recorded each test. The first camera, Locam, used a wide-angle lens and was placed approximately 80 feet perpendicular to the direction of the

TABLE 1 SUMMARY OF TEST CONDITIONS

TEST NO.	VEHICLE TYPE (lbs)	TARGET SPEED (mph)	SOIL TYPE	MAILBOX DESIGN	POST EMBEDMENT		POST SIZE (lbs/ft)	POINT OF IMPACT	TARGET IMPACT SEVERITY (ft-kips)
					DEPTH (in)	METHOD			
1	1800	20	Weak (S-2)	1-Post 2-Mailboxes (size 1-A)	37	Driven	2.0	14" to Right of Center	$24^{-3,+3}$
2	1800	20	Strong (S-1)	1-Post 2-Mailboxes (size 1-A)	37	Driven	2.0	14" to Right of Center	$24^{-3,+3}$
3	1800	60	Weak (S-2)	1-Post 2-Mailbox (size 1-A)	37	Driven	2.0	Center of Bumper	$216^{-21,+37}$
4	1800	60	Strong (S-1)	1-Post 1-Mailbox (size 2)	37	Driven	2.0	Center of Bumper	$216^{-21,+37}$

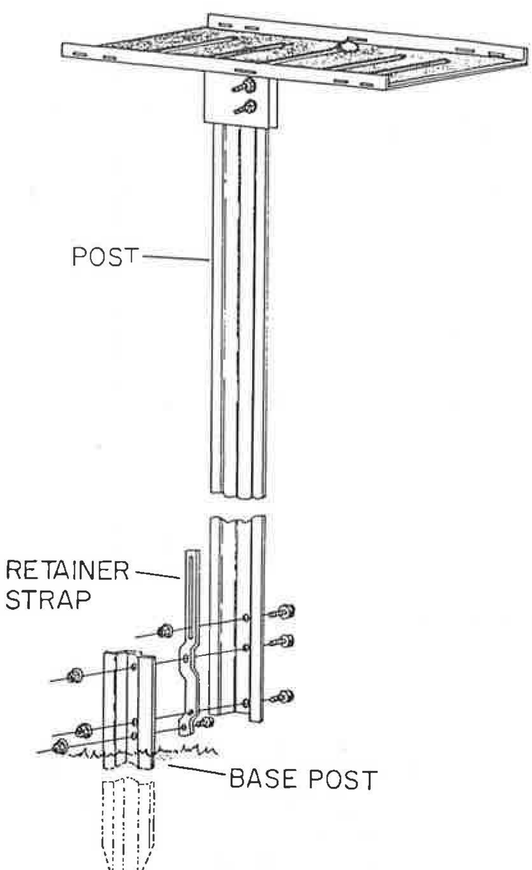


FIGURE 3 Single mailbox support system.

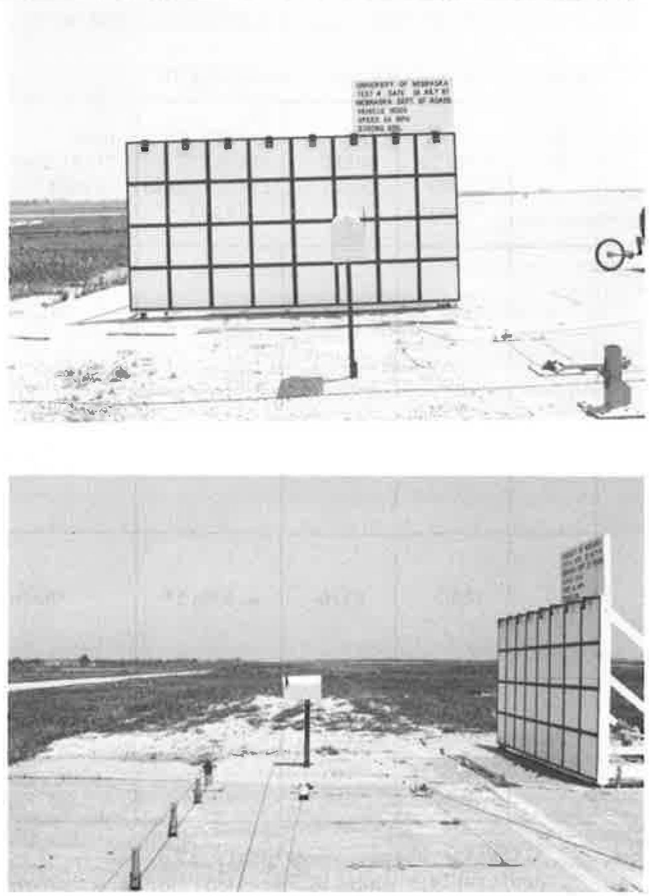


FIGURE 4 Photographs of the complete single mailbox system.

vehicle. The second camera, Photec IV, was also positioned perpendicular to the direction of the vehicle, at approximately 137 feet. After the tests, the film was analyzed using the Vanguard motion analyzer.

Tape or pressure switches positioned along the length of the impact area were activated by the vehicle to indicate the travel time over a known distance. This provided a quick check of the impact speed and also values for change in velocity.

PERFORMANCE STANDARDS

Currently, there are no established guidelines or performance criteria that directly deal with full-scale crash tests on mailbox supports. However, an American Association of State Highway and Transportation Officials (AASHTO) procedure guide (*8*) provides three very useful general criteria:

1. The mailbox support details should prevent mailboxes from separating from the post if struck by a vehicle.
2. Windshield penetration from the mailbox should be minimized. Single or multiple mailbox installations should not cause vehicle ramping or rollover as a result of a mailbox collision.

In addressing safety appurtenances, AASHTO requires all new roadside signs and luminaries on high speed highways, located within the suggested clear zone width, to be placed on breakaway supports unless they are located behind a barrier or crash cushion. Therefore, it was assumed that mailbox support systems should comply with the safety standards required for a breakaway or yielding device. Breakaway supports are all types of devices that are safely displaced under vehicle impact, whether the release mechanism is a slip plane, plastic hinges, fracture elements, or a combination of these.

According to AASHTO, "satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound (816.5 kg) vehicle, or its equivalent, striking a breakaway support at speeds from 20 mph to 60 mph (29.33 fps to 88 fps) (32 kmph to 97 kmph) does not exceed 15 fps (4.57 mps), but preferably does not exceed 10 fps (3.05 mps) or less" (*6*).

Other specifications require that detached elements, fragments, or other debris from the test article (mailbox assembly) shall not penetrate or show potential for penetrating the occupant compartment or provide undue hazard to other traffic. Also, the vehicle shall remain upright during and after the mailbox crash test (*1*).

The change in velocity, peak deceleration, maximum 10 ms average deceleration, and occupant displacement (free missile travel) were four types of data that were derived from the accelerometer readings. Change in velocity and occupant displacement are both time dependent. Due to this time dependency, guidelines have been established to determine the "duration of the event" for computation. The duration of the event is defined as the lesser of the following: (1) time between incipient contact and loss of contact between vehicle and the yielding support, or (2) the time for a free missile to travel a distance of 24 inches starting from rest with the same magnitude of vehicle decelerations (*9*).

TABLE 2 SUMMARY OF TEST RESULTS

TEST NO.	ACTUAL VEHICLE WEIGHT (lbs)	IMPACT SPEED (mph)	(a) CHANGE IN VELOCITY (left/right) (fps)	(b) PEAK DECELERATIONS (left/right) (g's)	(c) MAXIMUM 0.010 SEC AVERAGE DECELERATION (left/right) (g's)	(d) OCCUPANT DISPLACEMENT (left/right) (in)	ACTUAL IMPACT SEVERITY (ft-kips)
1	1840	20.5	1.9/3.2	8.2/22.6	2.74/4.60	1.30/2.10	25.8
2	1840	21.3	2.7/3.3	7.5/13.2	3.62/4.03	2.20/1.80	27.9
3	1840	63.6	4.4/4.5*	NA/NA**	NA/NA**	NA/NA**	248.6
4	1840	64.5	2.7/1.1	21.2/26.1	4.86/4.04	2.10/0.50	255.7

(a) allowable change in velocity 15 fps
preferable change in velocity 10 fps
(b) allowable threshold value of deceleration 20 g's
(c) allowable maximum 0.010 sec average deceleration 15 g's
(d) allowable occupant displacement 24 in.

*From high-speed film analysis
**Not available due to the breakage of the data cable

The time between incipient contact and loss of contact between vehicle and yielding support is not easily determined. By using the high-speed film, it was observed that contact between the vehicle and the support may take place over a long period of time if the vehicle moves over the mailbox. Therefore, after reevaluation of the accelerometer graphs, it was decided that the duration of the event was the time between contact and when the acceleration returned to and remained at zero. This decision was made because deceleration cannot remain at zero unless the vehicle has reached a constant velocity or has stopped.

After the test, the damage was assessed by the traffic accident data (TAD) scale (*10*) and the vehicle damage index (VDI) (*11*).

Because test conditions are sometimes difficult to control, a composite tolerance limit is presented. It is called the impact severity (IS). For structural adequacy, it is preferable for the actual impact severity to be greater than the target value rather than being below it. During low-speed tests, the goal is to determine the lower speed threshold for detaching the appurtenance. Then it is preferable to be on the low side of the target value. The IS target values for the 20 mph and 60 mph tests are $24^{-3,+3}$ ft-kips and $216^{-21,+37}$ ft-kips, respectively (*1*). Thus, the IS target values for the 20 mph tests range from 21 ft-kips to 27 ft-kips. For the 60 mph tests, the IS target values range from 195 ft-kips to 253 ft-kips.

TEST RESULTS

In the following section, each test will be explained along with the individual results. For all of the tests, an 1,840-pound Volkswagen Rabbit was used as the crash test vehicle. Also, the Franklin Steel Eze-Erect signpost, embedded 37 inches into the soil, was used for each test. Table 2 summarizes the results of the four tests.

The accelerometer data were used for the calculation of change in velocity, while the high-speed film was used as a backup system and check on the accelerometer results. For each test, plots of deceleration, change in, velocity, and occupant displacement versus time were recorded (*7*).

Test 1

Test 1 was conducted at an impact speed of 20.5 mph on the double mailbox system in the weak soil. The point of impact was 14 inches to the right of center. The results of Test 1 are shown in Table 3. A time-event summary is given in Table

TABLE 3 SUMMARY OF RESULTS, TEST 1

MAILBOX SUPPORT DATA		
Mailbox	2 boxes (size 1-A)	
Post Type	Steel U-post *	
Size	2.00 lbs/ft	
Embedment Method	Driven into Weak Soil (S-2)	
Embedment Depth	37 in.	
VEHICLE DATA		
Make	Volkswagen	
Model	Rabbit	
Year	1979	
Weight	1840 lbs.	
Impact Point	14 in. to right of center	
ACCELEROMETER DATA	Left	Right
Change in Velocity (ft/sec)	1.9	3.2
Duration of Event (sec) **	0.082	
Peak Deceleration (g's)	8.2	22.6
Maximum 0.010 sec Average Deceleration (g's)	2.74	4.60
Occupant Displacement (in)	1.30	2.10
VEHICLE DAMAGE CLASSIFICATION		
TAD	None	
VDI	12FCLN1	
Did test article penetrate the the passenger compartment?		NO
Was windshield broken?		NO

*Franklin Steel eze-erect sign post

**Time of Contact

Impact Velocity = 20.5 mph

Actual Impact Severity = 25.8 ft-kips

TABLE 4 TIME-EVENT SUMMARY FOR TEST 1

TIME (sec)	EVENT
0.000	Impact
0.006	Post begins bending
0.018	Post wrapping around bumper
0.050	Mailbox hits front end of hood
0.095	Mailbox and post being pushed over
0.147	First mailbox hits ground

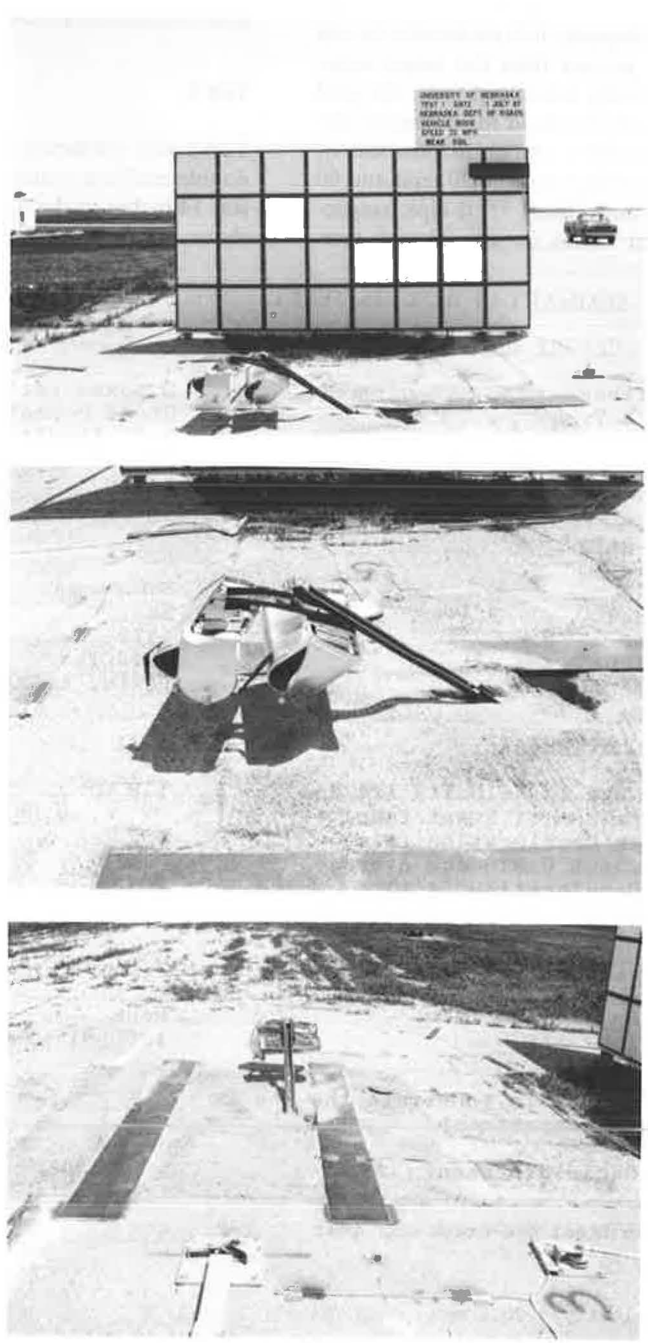


FIGURE 5 Damage to mailbox system, Test 1.

4. Upon impact, the post first wrapped around the bumper, and then the mailbox hit the front end of the hood. The car then continued to push the mailbox and post to the ground. While the car continued to move over the mailbox and post, the retainer strap held the top section of the post to the base post, which was not pulled out. Photos of the damage to the mailbox system are shown in Figure 5.

The vehicle received no damage with the exception of a small dent in the bumper. The damage was classified according to TAD and VDI scales, and the results are given in Table 3.

Test 2

Test 2 was performed at an impact speed of 21.3 mph on the double mailbox system in the strong soil. The point of impact was 14 inches to the right of center. A summary of the results of Test 2 is given in Table 5. Table 6 gives the time-event summary. Upon impact, the post began to wrap around the bumper, and then the mailbox hit the front end of the hood. As the car continued to travel over the mailbox assembly, the top section of the post broke away from the base post, which remained in the ground. This demonstrated the breakaway or slip feature. Photographs of the damage to the mailbox system are presented in Figure 6.

The only damage to the vehicle was a small dent in the front end of the hood and a minor dent in the bumper and front lower right fender. Table 5 gives the TAD and VDI damage ratings.

Test 3

Test 3 was conducted at an impact speed of 63.6 mph on the double mailbox system in the weak soil. The point of impact was center of bumper. The results of Test 3 are shown in Table 7. The time-event summary is given in Table 8. After impact, the post wrapped around the bumper while the mailbox struck the hood of the car. As the car traveled forward, the mailbox remained on the hood while the post assembly was pulled from the ground. At approximately 0.090 seconds after impact, the mailbox assembly started to lose contact

TABLE 5 SUMMARY OF RESULTS, TEST 2

<u>MAILBOX SUPPORT DATA</u>			
Mailbox	2 boxes (size 1-A)		
Post Type	Steel U-post *		
Size	2.00 lbs/ft		
Embedment Method	Driven into Strong Soil (S-1)		
Embedment Depth	37 in.		
<u>VEHICLE DATA</u>			
Make	Volkswagen		
Model	Rabbit		
Year	1979		
Weight	1840 lbs.		
Impact Point	14 in. to right of center		
<u>ACCELEROMETER DATA</u>	<u>Left</u>		<u>Right</u>
Change in Velocity (ft/sec)	2.7		3.3
Duration of Event (sec)**		0.100	
Peak Deceleration (g's)	7.5		13.2
Maximum 0.010 sec Average Deceleration (g's)	3.62		4.03
Occupant Displacement (in)	2.20		1.80
<u>VEHICLE DAMAGE CLASSIFICATION</u>			
TAD	None		
VDI	12FREE1		
Did test article penetrate the passenger compartment?	NO		
Was windshield broken?	NO		

*Franklin Steel eze-erect sign post

**Time of Contact

Impact Velocity = 21.3 mph

Actual Impact Severity = 27.9 ft-kips

TABLE 6 TIME-EVENT SUMMARY FOR TEST 2

TIME (sec)	EVENT
0.000	Impact
0.008	Post begins bending
0.037	Post wrapping around bumper
0.052	Mailbox hits front end of hood
0.101	Mailbox and post being pushed over
0.118	First mailbox hits ground

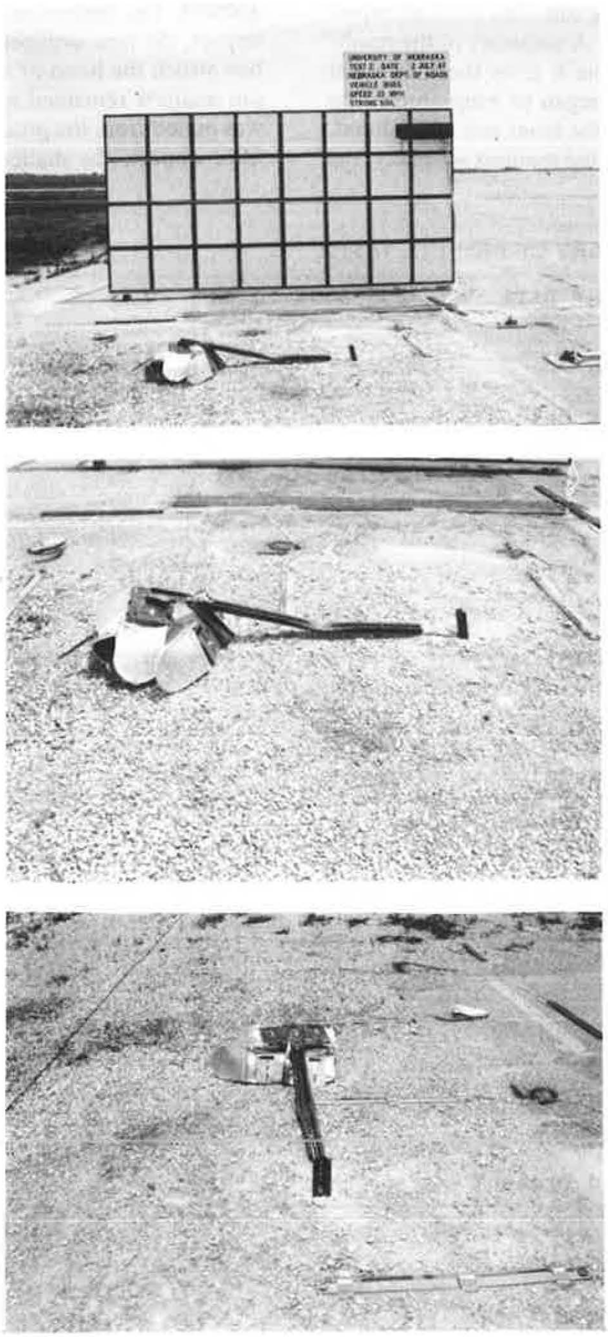


FIGURE 6 Damage to mailbox system, Test 2.

TABLE 7 SUMMARY OF RESULTS, TEST 3

MAILBOX SUPPORT DATA		
Mailbox	2 boxes (size 1-A)	
Post Type	Steel U-post *	
Size	2.00 lbs/ft	
Embedment Method	Driven into Weak Soil (S-2)	
Embedment Depth	37 in.	
VEHICLE DATA		
Make	Volkswagen	
Model	Rabbit	
Year	1979	
Weight	1840 lbs.	
Impact Point	Center of bumper	
ACCELEROMETER DATA	Left	Right
Change in Velocity (ft/sec)**	4.4 (Photec)	4.5 (Locam)
Duration of Event (sec)***	0.090	
Peak Deceleration (g's)	Not Available	
Maximum 0.010 sec Average Deceleration (g's)	Not Available	
Occupant Displacement (in)	Not Available	
VEHICLE DAMAGE CLASSIFICATION		
TAD	FC-1	
VDI	12TFCN5	
Did test article penetrate the passenger compartment?	NO	
Was windshield broken?	NO	

*Franklin Steel eze-erect sign post

**From high-speed film analysis

***Time of Contact

Impact Velocity = 63.6 mph

Actual Impact Severity = 248.6 ft-kips

TABLE 8 TIME-EVENT SUMMARY FOR TEST 3

TIME (sec)	EVENT
0.000	Impact
0.002	Post begins bending
0.006	Post wrapping around bumper
0.016	Mailbox hits hood
0.040	Mailbox on hood and post being pulled out
0.080	Post dragging through sand
0.090	Mailbox loses contact with hood

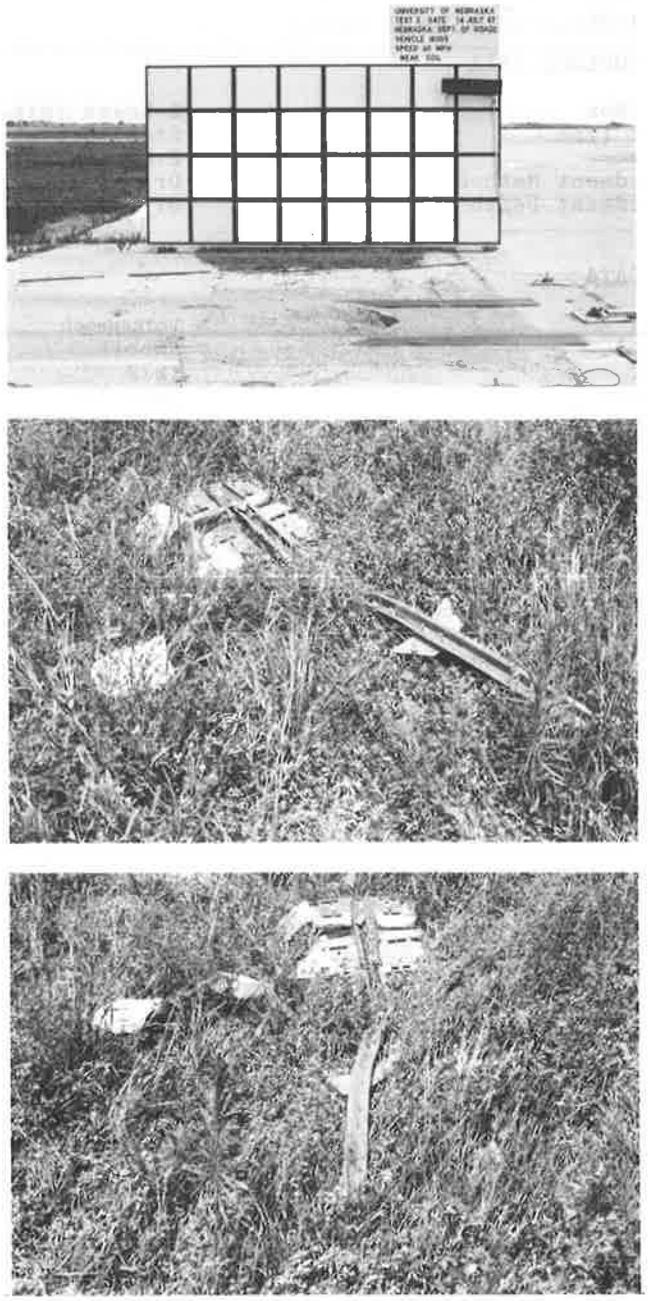


FIGURE 7 Damage to mailbox system, Test 3.

with the hood. The base post, top post, and mailbox all remained intact after they came to a rest 366 feet away, when they were run over by the vehicle. Damage to the mailbox system is shown in the photos given in Figure 7.

During Test 3, the data cable between the onboard Metraplex unit and tape recorder became tangled with the car cable guidance system. Thus, the cable broke before the car had reached the impact point and no accelerometer data were recorded. The NDOR decided not to rerun the test because the needed information could be obtained from the high-speed film and also the vehicle had remained stable and upright during and after collision.

The most noticeable damage to the vehicle was a punctured and dented hood and a fractured plastic grill plate. The TAD and VDI damage ratings are given in Table 7.

Test 4

Test 4 was performed at an impact speed of 64.5 mph on the single mailbox system in the strong soil. The point of impact was the center of bumper. A summary of the Test 4 results is given in Table 9. The sequential photos are shown in Figure 8 and a time-event summary is given in Table 10. As the vehicle moved through the impact, the mailbox post wrapped around the bumper, and then the top section of the post

TABLE 9 SUMMARY OF RESULTS, TEST 4

MAILBOX SUPPORT DATA		
Mailbox	1 box (size 2)	
Post Type	Steel U-post*	
Size	2.00 lbs/ft	
Embedment Method	Driven into Strong Soil (S-1)	
Embedment Depth	37 in.	
VEHICLE DATA		
Make	Volkswagen	
Model	Rabbit	
Year	1979	
Weight	1840 lbs.	
Impact Point	Center of bumper	
ACCELEROMETER DATE	Left	Right
Change in Velocity (ft/sec)	2.7	1.1
Duration of Event (sec)**	0.048	
Peak Deceleration (g's)**	21.2	26.1
Maximum 0.010 sec Average Deceleration (g's)	4.86	4.04
Occupant Displacement (in)	2.1	0.50
VEHICLE DAMAGE CLASSIFICATION		
TAD	FC-1	
VDI	12TFDW5	
Did test article penetrate the passenger compartment?	NO	
Was windshield broken?	NO	

*Franklin Steel eze-erect sign post

**Time of Contact

Impact Velocity = 64.5 mph

Actual Impact Severity = 255.7 ft-kips

separated from the base post. The base post remained embedded in the soil. The mailbox then struck the hood and was carried for a distance before being thrown from the car. The final resting place of the mailbox assembly was 130 feet from the point of impact. Photos of the damaged mailbox can be viewed in Figure 9.

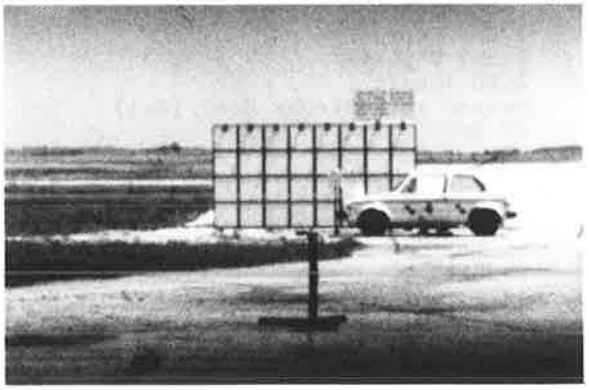
The vehicle's hood received the most significant damage, although the center grill area received some dents. Table 9 gives the TAD and VDI damage ratings for Test 4.

CONCLUSIONS

Four full-scale crash tests were conducted to evaluate the impact behavior of two NDOR mailbox support systems. One design used two mailboxes (Size 1-A) mounted side by side, and the other design consisted of one mailbox (Size 2) mounted to the top of the post.

The analysis of the four crash tests revealed the following:

1. In Tests 1 and 3, the actual impact severity was within the recommended limits. During Tests 2 and 4, the actual impact severity exceeded the recommended limits by 3.3 percent and 1.5 percent, respectively. Since the error was small, the tests were taken to be valid.
2. In each test the change in velocity of the vehicle was well below the recommended limit of 15 fps and also the preferable limit of 10 fps.
3. In each test where accelerometer data were available, the maximum 0.010-second average deceleration was well below the recommended limit of 15 *g*.
4. In all of the tests, the mailbox support system functioned as intended. It kept the mailbox attached to the top of the post, not allowing any detached fragments or elements to penetrate or show potential for penetration into the passenger compartment.
5. In each test the vehicle remained stable and upright during and after impact and also showed no potential for ramping or rolling over. Also, there were no severe damages assessed to the vehicle during each of the four tests.
6. The breakaway device functioned as intended for Tests 2 and 4. During Tests 1 and 3, which were conducted in weak



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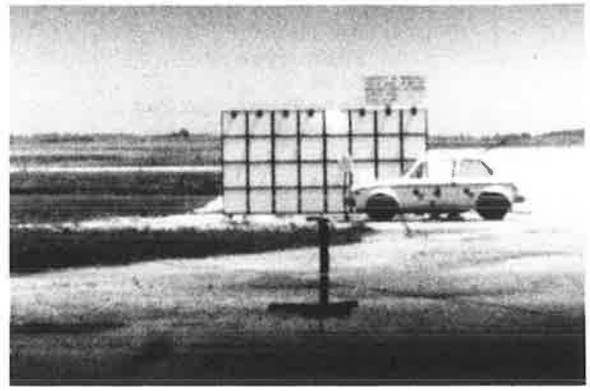

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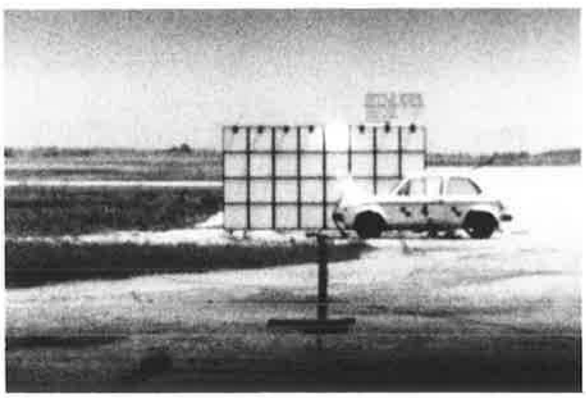

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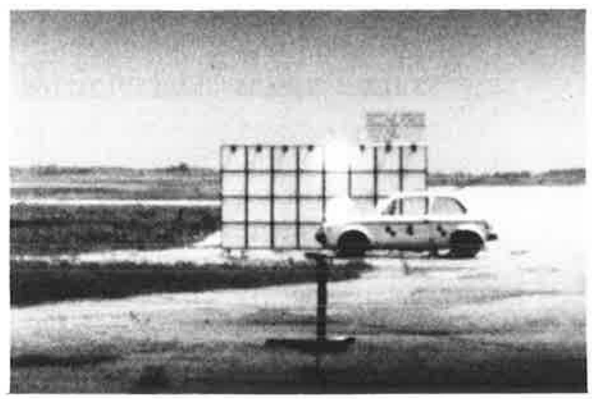

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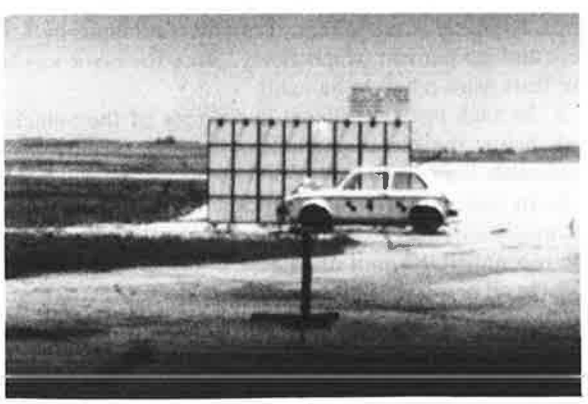

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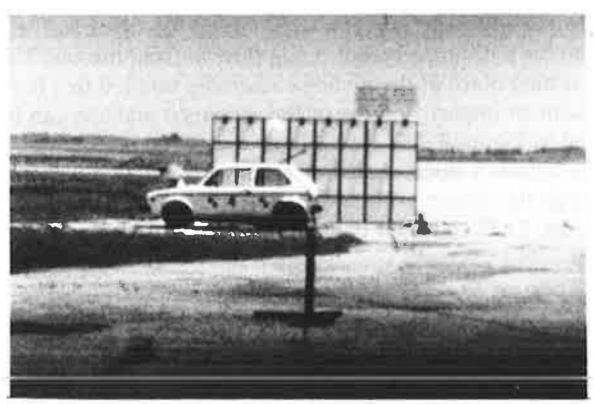

0.148 sec

FIGURE 8 Sequential photographs, Test 4.

TABLE 10 TIME-EVENT SUMMARY FOR TEST 4

TIME (sec)	EVENT
0.000	Impact
0.002	Post begins bending
0.010	Post wrapping around bumper
0.022	Post separates from base
0.026	Mailbox hits hood
0.040	Mailbox on hood
0.148	Mailbox leaving hood

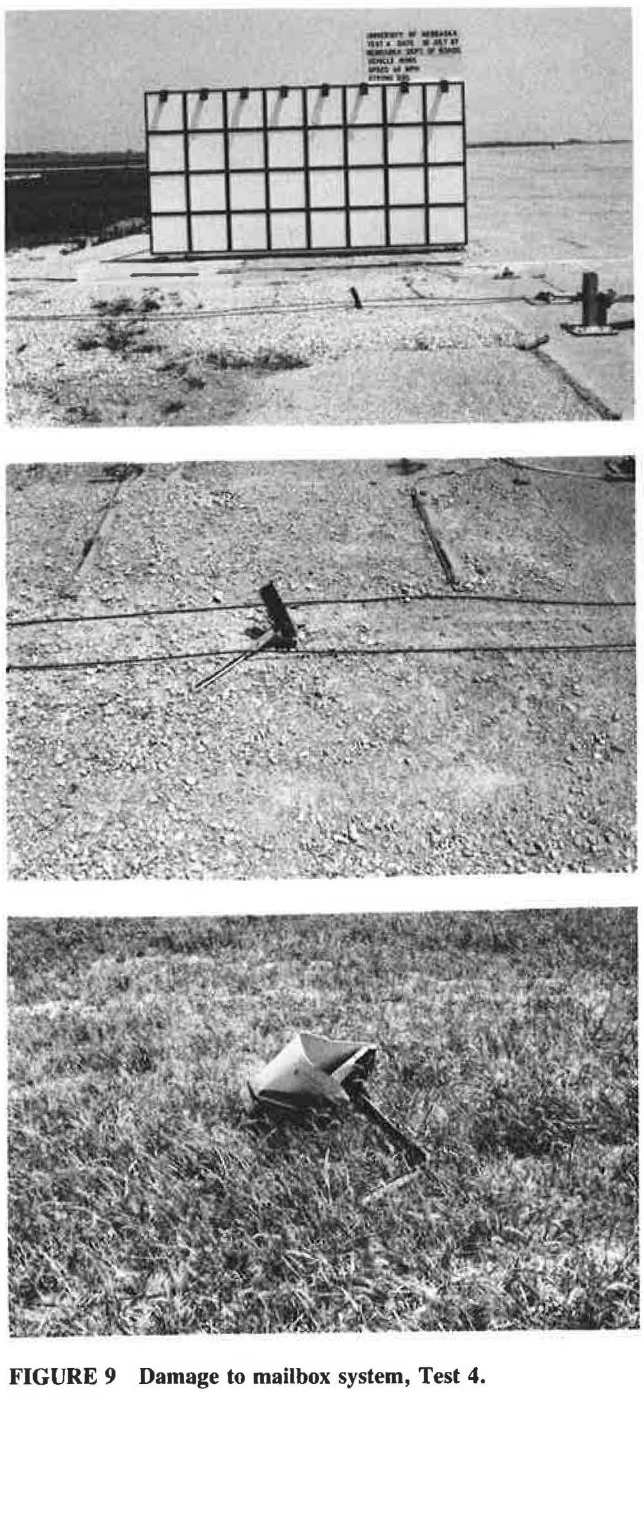

FIGURE 9 Damage to mailbox system, Test 4.

soil, the breakaway device did not function. In Test 1, the post system pushed over, allowing the vehicle to safely pass over it. In Test 3, the entire post system pulled out of the ground.

Based upon the above listed items, the results of each test are acceptable according to the NCHRP 230 guidelines, as modified by AASHTO 1985 guidelines.

RECOMMENDATIONS

In order to more securely tighten together the mailbox support system, it was suggested that the circular holes in the platform and L-shaped bracket be either punched to a larger size diameter or punched square so the carriage bolt shank can fit in the hole.

Also, it was suggested that the support system, consisting of the platform plates, the adapter plate, and L-shaped brackets, be treated with some type of protective surface coating such as paint or zinc plating. This would reduce the effects of rust on the system and possible mailbox detachment due to weakened steel parts.

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